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# उच्च तापमान पर दाब अनुपयोग के लिए अपकेन्द्रीय ढलवाँ उच्च मिश्रधातु इस्पात और निकेल से बनी नलियाँ — विशिष्टि

Indian Standard

# CENTRIFUGALLY CAST HIGH ALLOY STEEL AND NICKEL BASE TUBING FOR PRESSURE APPLICATION AT HIGH TEMPERATURE — SPECIFICATION

UDC 621·643·2 [ 669·15 - 194·56 - 142 ]

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NEW DELHI 110002

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**Price Group 3**

Steel Castings Sectional Committee, MTD 17

## FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Steel Castings Sectional Committee had been approved by the Metallurgical Engineering Division Council.

Austenitic steel centrifugally cast tubes are used in various industries, such as Chemicals, Petroleum Refining, Pharmaceuticals, Food Processing, Paper, Sugar, etc, for service under pressure at normal or elevated temperatures. Austenitic steels are also resistant to corrosion at normal or elevated temperatures.

Heat resistant alloy and nickel base steel centrifugally cast tubes are used for service at elevated temperatures with or without internal pressure in various industries such as Fertilizers, Chemicals, Petroleum Refining, Furnace and Power Plants, etc. The Heat resistant alloys are resistant to oxidation and corrosion at elevated temperatures.

In the preparation of this standard, assistance has been derived from the following publications:

BS 4534 : 1969 Weldable chromium nickel centrifugally cast steel tubes. British Standards Institution.

ASTM A-608-88 Specification centrifugally cast iron-chromium-nickel high alloy tubing for pressure application at high temperatures. American Society for Testing and Materials.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values ( *revised* )'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

# Indian Standard

# CENTRIFUGALLY CAST HIGH ALLOY STEEL AND NICKEL BASE TUBING FOR PRESSURE APPLICATION AT HIGH TEMPERATURE — SPECIFICATION

## 1 SCOPE

This standard covers the requirements for iron-chromium-nickel alloy tubes made by the centrifugal casting process intended for pressure applications at high temperature.

## 2 REFERENCES

The Indian Standards listed in Annex A are necessary adjuncts to this standard.

## 3 TERMINOLOGY

**3.1** For the purpose of this standard, the following definitions shall apply.

**3.1.1** *Cast* ( *Melt* )

The product of any of the following:

a) One furnace heat,

b) One crucible heat, or

c) A number of furnace or crucible heats of similar composition mixed in a ladle or tapped in separate ladles and poured simultaneously for making a casting.

**3.1.2** *Batch*

A group of castings of one grade of material, cast from the same melt and heat-treated together under identical conditions.

## 4 GRADES

This standard covers a total of fifteen grades of centrifugally cast steel tubes for pressure application at high temperature to the extent relevant.

## 5 SUPPLY OF MATERIAL

General requirements relating to supply of steel castings shall be as laid down in IS 8800 : 1986.

## 6 MANUFACTURE

The steel for the tube shall be made by electric arc or electric induction or such other processes as may be agreed to between the purchaser and the manufacturer.

## 7 PARTICULARS TO BE SPECIFIED WHILE ORDERING

For the benefit of the purchaser, particulars to be specified while ordering for steel castings to this specification are given in Annex B.

## 8 CHEMICAL COMPOSITION

**8.1** The ladle analysis of steel when carried out either by the method specified in IS 228 and its relevant parts or any other established instrumental/chemical methods shall be as given in Table 1. In case of dispute the procedure given in IS 228 shall be the referee method. However, where the method is not given in IS 228, the referee method shall be agreed to between the purchaser and the manufacturer.

**8.2** The manufacturer shall carry out analysis from a sample of each melt of steel and, if so specified by the purchaser at the time of enquiry and order, shall supply a test certificate of chemical analysis of the sample of steel for each melt.

### 8.3 Product Analysis

If specified at the time of enquiry and order, the product analysis may be carried out from a test piece or from a casting representing each melt. Drillings for analysis shall be taken from not less than 6 mm beneath the cast surface, and in such a manner as not to impair the usefulness of the casting selected. The permissible variation in product analysis from the limits specified in Table 1 shall be as given in IS 6601 : 1987.

### 8.4 Residual Elements

**8.4.1** Elements not specified in Table 1 shall not ordinarily be added to the steel and all reasonable precautions shall be taken to prevent contamination from the scrap, etc, to keep them as low as practicable.

**8.4.2** Analysis and reporting of the analysis in the test certificate for the residual elements shall be done only when so specified by the purchaser in the enquiry and order. However, the manufacturer shall ensure that the residual elements are within the limits specified.

**8.4.3** In the interest of uniform welding the limit for copper as 0·30 percent, *Max* may be specified by the purchaser.

## 9 WORKMANSHIP AND FINISH

**9.1** The tubes shall be in accordance with the drawings and specific requirements stipulated at the time of enquiry and order.

**Table 1 Chemical Composition**

( *Clause* 8.1 )

| Constituent | Grade, Requirements, Percent* | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| Carbon | 0·08 | 0·08 | 0·08 | 0·20 | 0·20 | 0·20-<br>0·50 | 0·20-<br>0·50 | 0·20-<br>0·50 | 0·20-<br>0·50 | 0·20-<br>0·50 | 0·20-<br>0·60 | 0·20-<br>0·50 | 0·35-<br>0·75 | 0·35-<br>0·75 | 0·35-<br>0·75 |
| Silicon | 2·00 | 2·00 | 2·00 | 2·00 | 2·00 | 2·00 | 2·00 | 2·00 | 2·00 | 2·00 | 2·50 | 2·00 | 2·50 | 2·50 | 2·50 |
| Manganese | 1·50 | 1·50 | 1·50 | 1·50 | 2·00 | 1·00 | 2·00 | 2·00 | 2·00 | 2·00 | 2·00 | 2·00 | 2·00 | 2·00 | 2·00 |
| Sulphur | 0·04 | 0·04 | 0·04 | 0·04 | 0·04 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 |
| Phosphorus | 0·04 | 0·04 | 0·04 | 0·04 | 0·04 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 | 0·05 |
| Chromium | 18·00-<br>21·00 | 18·00-<br>21·00 | 18·00-<br>21·00 | 22·00-<br>26·00 | 23·0-<br>27·0 | 26·0-<br>30·0 | 18·0-<br>20·0 | 26·0-<br>30·0 | 23·0-<br>27·0 | 23·0-<br>27·0 | 28·0-<br>32·0 | 19·0-<br>23·0 | 13·0-<br>17·0 | 17·0-<br>21·0 | 15·0-<br>19·0 |
| Nickel | 8·00-<br>11·0 | 9·00-<br>12·00 | 9·00-<br>12·00 | 12·00-<br>15·00 | 19·0-<br>22·0 | 4·0-<br>7·0 | 8·0-<br>10·0 | 8·0-<br>10·0 | 11·0-<br>14·0 | 18·0-<br>22·0 | 18·0-<br>22·0 | 23·0-<br>27·0 | 33·0-<br>37·0 | 37·0-<br>41·0 | 64·0-<br>68·0 |
| Molybdenum | — | 2·00-<br>3·00 | — | — | — | 0·5 | 0·5 | 0·5 | 0·5 | 0·5 | 0·5 | 0·5 | 0·5 | 0·5 | 0·5 |
| Columbium | — | — | † | — | — | — | — | — | — | — | — | — | — | — | — |

NOTE — Restricted ranges for various elements within the limits stipulated above may be ordered if agreed to at the time of enquiry and order.

**Max*, unless a range is specified.

†Grade 3 shall have a columbium content of not less than 8 times the carbon content and not more than 1·0 percent.

**9.2** The purchaser shall specify the tolerances, if any, required by him. Otherwise the general tolerance specified in **13** shall apply.

**9.3** The tubes shall be free from defects that will adversely affect their application or utility of the tubes.

## 10 HEAT TREATMENT

**10.1** The castings shall be heat treated in a properly constructed furnace, having adequate means of temperature control which shall permit the whole of the casting being uniformly heated to the necessary temperature. All castings shall be suitably heat treated so as to attain the specified mechanical properties.

**10.2** Grades 1, 2, 3, 4 and 5 shall be heat treated according to the requirements specified in Table 2 unless otherwise agreed between the purchaser and the manufacturer. All other grades shall be supplied in either as cast or annealed condition unless otherwise agreed between the purchaser and the manufacturer.

**10.3** Test samples shall be drawn from the end portion of the tube itself and shall not be cut before heat-treatment, if any. However if separated from the tube the test pieces shall be heat treated along with the tubes they represent.

**Table 2 Heat Treatment Requirements**

( *Clause* 10.2 )

| Grade | Heat Treatment |
|---|---|
| 1, 2, 3 | Heat to 1 050°C, *Min*, hold for sufficient time quench in water or rapid cool by other means so as to develop acceptable corrosion resistance. |
| 4, 5 | Heat to 1 080°C, *Min*, hold for sufficient time, quench in water or rapid cool by other means so as to develop acceptable corrosion resistance. |

## 11 MECHANICAL TEST

**11.1** The tensile test shall be carried out in accordance with IS 1608 : 1972. The relevant mechanical properties shall be as given in Table 3.

**11.2** Unless otherwise specified, one tensile test specimen shall be taken longitudinally from one tube out of a lot of every ten tubes cast.

**11.3** Care shall be taken to ensure that the machined specimens are so located as to avoid any unsoundness associated with the external surface or the bore.

**Table 3 Mechanical Properties of Cast Steel Tubing for Pressure Application at High Temperature**

( *Clause* 11.1 )

| Grade | Tensile Strength ( MPa ), *Min* | Yield Stress ( MPa ), *Min* | Elongation ( Percent ), *Min* |
|---|---|---|---|
| 1 | 480 | 205 | 35·0 |
| 2 | 480 | 205 | 30·0 |
| 3 | 480 | 205 | 30·0 |
| 4 | 480 | 205 | 30·0 |
| 5 | 450 | 190 | 30·0 |
| 6 | 515 | 240 | 8·0 |
| 7 | 485 | 240 | 25·0 |
| 8 | 585 | 275 | 9·0 |
| 9 | 515 | 240 | 10·0 |
| 10 | 450 | 240 | 10·0 |
| 11 | 450 | 240 | 10·0 |
| 12 | 435 | — | 8·0 |
| 13 | 450 | — | 4·0 |
| 14 | 450 | — | 4·0 |
| 15 | 415 | — | — |

## 12 PRESSURE TESTING

**12.1** All tubes shall be subjected to an internal air pressure of at least 5 kgf/cm$^2$ for a minimum duration of 1 min, while immersed in clear water. Alternatively, the entire outer surface of the tube may be made wet with sulphur free soap solution. No leaks shall be permitted in the usable portion of the tube.

**12.2** When so specified by the purchaser in the enquiry and the order, a hydraulic test shall be carried out; the details of the test shall be as agreed to between the purchaser and the manufacturer.

**12.3** The cast tubes shall not be peened, plugged or impregnated, to stop leakages. However unless otherwise specified at the time of enquiry and order, rectification and upgradation of the cast tubes by welding may be carried out in accordance with the approved procedures as laid down in the relevant clause of the standard.

**12.4** The water used for pressure testing shall be clean, potable and shall not contain more than 20 ppm chloride ions.

## 13 DIMENSIONAL TOLERANCES

**13.1** Each tube length in the condition as specified in the enquiry and order shall be dimensionally checked and, unless otherwise specified at the time of enquiry and order shall comply with the following requirements.

**13.2** Unless otherwise specified, the tolerance on length shall be as follows:

| *Outside Dia of Tube*, mm | *Permissible Excess Length*, mm |
|---|---|
| Up to 300 | 6 |
| Above 300 and up to 600 | 13 |

NOTE — No short length shall be acceptable.

**13.3** The tubes shall not deviate from the true axis by more than 2·0 mm in 2 500 mm. If necessary the tubes may be straightened mechanically.

**13.4** Tolerances on the outside and inside diameters shall comply with the following requirements unless otherwise agreed between the purchaser and the manufacturer.

**13.4.1** *As Cast Tubes*

The tolerances on outside diameter shall not exceed the limits given in Table 4.

**13.4.2** *Machined Tubes*

The tolerances on machined outside and inside diameters shall be:

| | |
|---|---|
| Tolerance on outside diameter | + 1·5 mm<br>− 0 mm |
| Tolerance on inside diameter | + 0 mm<br>− 1·5 mm |

**Table 4 Tolerances on Outside Diameters of as Cast Tubes**

( *Clause* 13.4.1 )

| Specified Outside Diameter of Tube, mm | Permissible Deviations from Specified Outside Dia, mm |
|---|---|
| Up to 100 | ± 2·0 |
| Over 100 to 300 | ± 2·5 |
| Over 300 to 600 | ± 3·0 |

### 13.5 Concentricity

The machined tubes shall not be eccentric by more than 1·5 mm. Eccentricity shall be measured by measuring the thickness at four different orientations, 90° apart from each other at both the ends of the tubes.

### 13.6 End Preparation Profile

The end preparation profile shall be checked to ensure conformity with the requirements of the enquiry and the order.

### 13.7 Wall Thickness

The wall thickness shall not exceed the specified minimum wall thickness by more than the limits shown in Table 5.

**Table 5 Permissible Variation in Wall Thickness**

| Specified Outside Diameter of Tube ( mm ) | Permissible Increase Over the Specified Minimum Wall Thickness ( mm ) |
|---|---|
| Up to and including 300 | 2·5 |
| Over 300 | 3·5 |

## 14 SURFACE TEXTURE

### 14.1 As Cast Surface

These cast external and internal surfaces of each tube when not required to be machined shall be visually examined after being thoroughly cleaned by either sand blasting or by any other means. The surfaces so examined shall be free of injurious defects like cracks, lamination, or any other imperfections that encroach upon the minimum wall thickness of the tube. Visual surface defects that have been found to be not encroaching upon the minimum wall thickness shall be blended either by machining or grinding the surface into the surrounding unaffected surface area of the tube.

### 14.2 Minimum Sound Wall Thickness

**14.2.1** The minimum sound wall thickness is the thickness which would remain, should all the porosity and roughness associated with the internal and external cast surfaces, exceeding a specified level, be removed by concentric machining.

**14.2.2** In the case of tubes supplied with as cast internal surface, and having a specified minimum sound wall thickness in order to compensate for unsoundness which may be associated with the cast internal surface, it is necessary to add an internal unsoundness allowance. The actual allowance that will be necessary in any specific cast will vary according to the total as cast thickness of the tube, and also the standard of soundness requirements specified, etc. In addition, an allowance may be required to accommodate any minor imperfection and roughness associated with the as cast external surface.

**14.3** In case of as cast tube with minimum sound wall requirement, the allowance for internal unsoundness and, if required, external roughness shall be as specified in the enquiry and order or as may be agreed between the manufacturer and the purchaser at the enquiry stage.

**14.4** The nominal dimensions of the tube shall be derived from the required bore diameter, the internal unsoundness allowance, the minimum sound wall thickness and the external roughness allowance.

### 14.5 Machined Surface

The machined surface shall be free of any tool marks or burr, etc, and the surface roughness if specified shall conform to the requirements of the enquiry and order.

## 15 REPAIR BY WELDING

Subject to prior approval from purchaser, repair by welding may be carried out.

## 16 OPTIONAL TESTS

### 16.1 Metal Structure and Etching Tests

**16.1.1** Etching tests shall be made on transverse or longitudinal sections from any tube, and shall show sound and reasonably uniform material within the specified sound wall area, free from injurious laminations and similar objectionable defects.

The macroetch test may be carried out in accordance with IS 12037 : 1987. If the specimen from either end of any length shows objectionable defects, one re-test shall be permitted from that end. If this fails, the length shall be cut back until sound metal is obtained.

**16.2** The nature of the heat-resistant alloys produced by the centrifugal process may cause them to exhibit a difference in grain size from length to length and within an individual length. This difference in grain size shall not be cause for rejection.

### 16.3 Radiographic Inspection

The turned and bored tubing may be examined for internal defects by means of X-rays of gamma rays.

### 16.4 Liquid Penetrant Inspection

Liquid penetrant inspection may be performed only on those areas of the tubing which have been suitably prepared for this type of inspection by grinding, machining, polishing, or other processing.

**16.5** Unless otherwise agreed upon, when non-destructive testing is to be done, the cast tubes shall be examined as follows:

a) Liquid penetrant examination as per IS 3658 : 1988, and

b) Radiographic examination as per IS 2595 : 1978.

**16.5.1** Unless otherwise agreed upon, the following shall be the acceptance standards:

a) IS 11732 : 1986 for liquid penetrant inspection, and

b) IS 12938 : 1990 for radiographic inspection.

## 17 METHOD OF SAMPLING

The method of sampling the steel castings for the purpose of chemical analysis and mechanical tests including re-test shall be in accordance with IS 6907 : 1992.

## 18 METHOD OF MARKING

**18.1** Each cast tube shall be legibly marked with the following:

a) The number or identification mark by which it is possible to trace the melt and the heat-treatment batch from which it was made;

b) The manufacturer's initials or trade-mark; and

c) Other identification marks in accordance with any agreement between the purchaser and the manufacturer.

NOTE — It is recommended that a minimum of markings be used.

**18.2** By agreement between the purchaser and the manufacturer, castings complying with the requirements of this standard may, after inspection, be legibly marked with an acceptance mark.

**18.2.1** The castings may also be marked with the Standard Mark. ( Details are available with the Bureau of Indian Standards ).

# ANNEX A

( *Clause* 2 )

## LIST OF REFERRED INDIAN STANDARDS

| *IS No.* | *Title* | *IS No.* | *Title* |
|---|---|---|---|
| 228 | Methods for chemical analysis of steel ( *second revision* ) | 6907 : 1992 | Methods of sampling of steel castings ( *second revision* ) |
| 1608 : 1972 | Methods for tensile testing of steel products ( *first revision* ) | 8800 : 1986 | Technical delivery conditions for steel castings ( *second revision* ) |
| 2595 : 1978 | Code of practice for radiographic testing ( *first revision* ) | 11732 : 1986 | Acceptance standards for dye penetrant inspection of steel castings |
| 3658 : 1981 | Code of practice for liquid penetrant flaw detection ( *first revision* ) | 12938 : 1990 | Acceptance standards for radiographic inspection of steel castings |
| 6601 : 1978 | Permissible deviations in chemical composition for products analysis of steel castings ( *first revision* ) | 12037 : 1987 | Macrographic examination by sulphur print ( Baumann method ) |

# ANNEX B

( *Clause* 7 )

## INFORMATION TO BE SUPPLIED BY THE PURCHASER

### B-1 BASIS FOR ORDER

While placing an order for the purchase of steel castings covered by this standard, the purchaser should specify the following:

a) Material specification;
b) Drawing or reference number of the pattern ( if supplied by the purchaser ), along with a copy of the drawing;
c) Optional/Additional tests required, if any;
d) Whether the castings are to be inspected and tested in the presence of the purchaser's representative;
e) Condition of delivery;
f) Any special requirement; and
g) Test report, if required.

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